

METHODS OF FORMING SEMICONDUCTOR DEVICES HAVING FIELD OXIDES IN  
TRENCHES AND DEVICES FORMED THEREBY

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5 filed on January 10, 2003, the contents of which are incorporated herein by reference in their  
entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

10 The present invention relates generally to semiconductor devices and methods of forming semiconductor devices, and more particularly to methods of forming semiconductor devices having field oxides in trenches.

2. Description of the Related Art

15 Field oxides in a semiconductor device are used to isolate devices from neighboring devices. As semiconductor devices become highly integrated, field oxides occupying small areas and having superior insulation characteristics are required.

Field oxides can be formed by using a shallow trench isolation (STI) method or by using a local oxidation of silicon (LOCOS) method. According to the STI method, a 20 semiconductor substrate is etched to form a trench having a predetermined depth, and the trench is filled with insulation layers. The STI method can form field oxides occupying small areas and having a superior insulation characteristics in comparison with a local oxidation of silicon (LOCOS) method of forming a thermal oxide at a semiconductor substrate.

Semiconductor devices may be classified into volatile memory devices and a non-volatile memory devices. A volatile memory device is a memory device which will lose data 25 stored in a memory cell when the power supply is cut down. A non-volatile memory device is a device which will retain data stored in a memory cell even though the power supply is cut down. Volatile memory device include dynamic random access memory (DRAM) devices and a static random access memory (SRAM) devices. A flash memory device is a non-volatile memory device.

Generally, when data is stored in a memory cell of a flash memory device or erased there from, a higher operation voltage is needed. Thus, in general flash memory devices have a high-voltage region where devices are formed so as to control high voltages.

Figs. 1 and 2 illustrate by cross-sectional views a conventional method of forming a flash memory device having field oxides. In the Figs. 1 and 2, reference letters "a" and "b" indicate a cell region and a high-voltage region, respectively.

Referring to Figs. 1 and 2, a semiconductor substrate 1 having the cell region "a" and the high-voltage region "b" is prepared. A channel stop impurity-doped region 2 is formed into the semiconductor substrate 1 of the high-voltage region "b" with a predetermined depth. A hard mask layer 3 is formed on a surface of the semiconductor substrate 1 having the channel stop impurity-doped region 2. The hard mask layer 3 is patterned to form a cell trench 4a to define an active region at the cell region "a" and to simultaneously form a high-voltage trench 4b exposing the channel stop impurity-doped region 2 at the high-voltage region "b". A higher voltage than a power voltage is supplied on the high-voltage region "b". As the high-voltage trench 4b has a deeper depth and a wider width. The cell trench 4a and the high-voltage trench 4b are simultaneously formed. Thus, the cell trench 4a and the high-voltage trench 4b have the same depth. Furthermore, the cell trench 4a has a narrower width than the high-voltage trench 4b. As a result, an aspect ratio of the cell trench 4a is higher than the high-voltage trench 4b.

A field oxide layer 5 is formed on a surface of a semiconductor substrate 1 to fill the cell trench 4a and the high-voltage trench 4b.

The field oxide layer 5 is planarized to expose the hard mask layer 3 and to form a cell field oxide 5a filling the cell trench 4a and a high-voltage field oxide 5b filling the high-voltage trench 4b. A high-voltage gate pattern (not illustrated) is formed at the high-voltage region "b", and an impurity-doped region 7 is formed into an active region at both sides of the high-voltage gate pattern. The impurity-doped region 7 corresponds to source/drain regions of a high-voltage transistor.

In the described conventional method, voids 6 may be formed in the cell field oxides 5a due to the high aspect ratio of the cell trenches 4a. The voids 6 may deteriorate reliability of a semiconductor device.

The voids 6 may be prevented by reducing the depth of the cell trench 4a. In this case, however, the depth of the high-voltage trench 4b is also reduced. As a result, a punch through may occur between the source/drain regions 7 for the high-voltage transistor at the both side walls of the high-voltage field oxide 5b. Additionally, as the channel stop impurity-doped region 2 is close to the surface of the active region at the high-voltage region b, a channel region (not illustrated) under the high-voltage transistor has a high-doping

concentration to increase a threshold voltage of the high-voltage transistor. This can result in reliability problems of the high-voltage transistor.

## SUMMARY OF THE INVENTION

5 According to an embodiment of the present invention, a semiconductor substrate is prepared. An upper trench at a predetermined region of the semiconductor substrate and a bottom trench at a bottom surface of the upper trench are formed. A field oxide is formed to fill the bottom trench and the upper trench. At this time, the upper trench has a wider width than the bottom trench.

10 The upper trench and the bottom trench may be formed by the following sequences. First, an assistant trench is formed at a predetermined region of the semiconductor substrate. A trench mask layer is formed on the semiconductor substrate having the assistant trench. An opening is formed to expose the assistant trench and a predetermined region of the semiconductor substrate at both sides of the assistant trench by patterning the trench mask layer. Then, the upper trench and the bottom trench are formed by anisotropically etching the exposed bottom surface of the assistant trench and the semiconductor substrate. At this time, the upper trench has substantially the same width as the opening and the bottom trench has substantially the same width as the assistant trench. Alternatively, the upper trench and the bottom trench may be formed by the following sequences. That is, an upper trench is formed 15 at a predetermined region of the semiconductor substrate. Then, the bottom trench is formed by selectively etching a bottom predetermined region of the upper trench.

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According to another aspect of the present invention, a semiconductor substrate having a first region and a second region is prepared. A first trench is formed at a predetermined region of the semiconductor substrate at the first region and a second trench 25 composed of an upper trench at a predetermined region of the semiconductor substrate at the second region and a bottom trench at the bottom of the upper trench is formed. A first field oxide is formed to fill the first trench and a second field oxide is formed to fill the second trench. At this time, the first trench and the upper trench have identical depths from a surface of the semiconductor substrate and the upper trench has a wider width than the bottom trench.

30 According to another aspect of the present invention, the first trench and the second trench may be formed by the following sequences. First, an assistant trench is formed at a predetermined region of the semiconductor substrate at the second region. A trench mask layer is formed on the semiconductor substrate having the assistant trench. The trench mask layer is patterned to form a first opening exposing a predetermined region of the

semiconductor substrate at the first region and a second opening exposing the assistant trench and a predetermined region of the semiconductor substrate at both sides of the assistant trench at the second region. Then, the semiconductor substrate and a bottom surface of the assistant trench exposed by the first opening and the second opening are anisotropically etched to form the first trench and the second trench. At this time, the upper trench has substantially the same width with the second opening and the bottom trench has substantially the same width as the assistant trench. Alternatively, the first trench and the second trench may be formed by the following sequences. That is, a first trench is formed at a predetermined region of the semiconductor substrate at the first region and an upper trench is formed at a predetermined region of the semiconductor substrate at the second region. And then, a bottom trench is formed by selectively etching a predetermined region of a bottom surface of the upper trench.

According to still another aspect of the present invention, a semiconductor substrate having a first region, a second region and a key region is prepared. An assistant trench is formed at a predetermined region of a semiconductor substrate at the second region and an initial key trench is formed at a predetermined region of the semiconductor substrate at the key region. A trench mask layer is formed on a surface of the semiconductor substrate having the assistant trench and the key trench. The trench mask layer is patterned to form a first opening exposing a predetermined region of the semiconductor substrate at the first region, a second opening exposing the assistant trench and a predetermined region of the semiconductor substrate at both sides of the assistant trench at the second region and a key opening exposing the initial key trench and a predetermined region of the semiconductor substrate at the key region. The bottom surface of the assistant trench and the exposed semiconductor substrate are anisotropically etched to form a first trench at the first region, a second trench composed of an upper trench at a surface of the semiconductor substrate at the second region and a bottom trench at a bottom surface of the upper trench, and a key trench composed of an upper key trench at a surface of the semiconductor substrate at the key region and a bottom key trench at a bottom surface of the upper key trench. Then, a first field oxide is formed in the first trench, a second field oxide is formed in the second trench and a key field oxide is formed in the key trench. At this time, the first trench, the upper trench and the upper key trench have like depths from a surface of the semiconductor substrate and the upper trench has substantially the same width as the second opening. Also, the bottom trench has substantially the same width as the assistant trench.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 and 2 illustrate cross-sectional views according to a conventional method of forming a flash memory device having field oxides.

5 Figs. 3 through 5 illustrate cross-sectional views of semiconductor devices for showing a method of forming field oxides according to an embodiment of the present invention.

Figs. 6 through 9 illustrate cross-sectional views of semiconductor devices for showing a method of forming field oxides according to another embodiment of the present invention.

10 Figs. 10 through 13 illustrate cross-sectional views of semiconductor devices for showing a method of forming field oxides according to still another embodiment of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

15 The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. The embodiments described herein are provided so that this disclosure will be thorough and complete, and will fully convey the 20 scope of the invention to those skilled in the art.

In the drawings, the thickness of layers and regions are exaggerated for clarity. It will be understood that when an element such as a layer, region or substrate is referred to as being “on” another element, it can be directly on the other element or intervening elements may also be present.

25 Furthermore, relative terms, such as “beneath”, may be used herein to describe one element’s relationship to another elements as illustrated in the Figures. It will be understood that relative terms are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. For example, if the device in the Figures is turned over, elements described as “below” other elements would then be oriented “above” the other 30 elements. The exemplary term “below”, can therefore, encompasses both an orientation of above and below.

It will be understood that although the terms first and second are used herein to describe various regions, layers and/or sections, these regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one region, layer or

section from another region, layer or section. Thus, a first region, layer or section discussed below could be termed a second region, layer or section, and similarly, a second without departing from the teachings of the present invention. Like numbers refer to like elements throughout.

5       First Embodiment.

Figs. 3 through 5 illustrate cross-sectional views of semiconductor devices for showing a method of forming field oxides according to a first embodiment of the present invention. In the Figs. 3 through 5, reference letters c, d and e indicate a cell region, a high-voltage region and a key region, respectively.

10       Referring to Fig. 3, an assistant trench mask layer 103 is formed on the surface of a semiconductor substrate 101 having the cell region c, the high-voltage region d and key region e. The assistant trench mask layer 103 may be formed by a photoresist layer. An align key is formed for aligning a photomask in a subsequent photolithography process at the key region e. The key region e may be located in a scribe line.

15       The assistant trench mask layer 103 is patterned to form an assistant trench opening 105 exposing a predetermined region of a semiconductor substrate 101 at the high-voltage region d and exposing an initial key opening 106 exposing a predetermined region of a semiconductor substrate 101 at the key region e. The assistant trench opening 105 may have a width W1.

20       The semiconductor substrate 101 exposed by the assistant trench opening 105 and the initial key opening 106 is selectively etched to form an assistant trench 107 in the high-voltage region d and an initial key trench 109 in the key region e. The assistant trench 107 and the initial key trench 109 may have a depth d1.

25       Impurity ions are implanted by using the patterned assistant trench mask layer 103 as an ion-implantation mask to form a channel stop impurity-doped region 111. The channel stop impurity-doped region 111 is formed into the semiconductor substrate 101 spaced from the bottom of the assistant trench 107 with a depth d2. The channel stop impurity-doped region 111 is preferably formed to have a high concentration and an identical conductive type with the semiconductor substrate 101 around the channel stop impurity-doped region 111.

30       For example, if the semiconductor substrate 101 around the channel stop impurity-doped region 111 is doped by P-type impurities, the channel stop impurity-doped region 111 is also doped by P-type impurities but with a higher concentration than the semiconductor substrate 101.

A width W2 of the channel stop impurity-doped region 111 is preferably identical with the width W1 of the assistant trench opening 105. That is, the width W1 of the assistant trench opening 105 is preferably determined by the width W2 of the channel stop impurity-doped region 111. When the channel stop impurity-doped region 111 is formed, an impurity-doped region 111' may be formed into the semiconductor substrate 101 under the initial key trench 109.

Referring to Fig. 4, the assistant trench mask layer 103 is removed from the semiconductor substrate 101 having the channel stop impurity-doped region 111.

A trench mask layer 113 is formed on a surface of the semiconductor substrate 101.

The trench mask layer 113 may be formed of a hard mask layer. The hard mask layer may be formed of a buffer insulator and a silicon nitride that are sequentially stacked. Alternatively, the trench mask layer 113 may be formed of a photoresist layer.

The trench mask layer 113 is patterned to form a cell opening 115 exposing a predetermined region of the semiconductor substrate 101 at the cell region c, a high-voltage opening 116 exposing a predetermined region of the semiconductor substrate 101 at the high-voltage region d and a key opening 117 exposing a predetermined region of the semiconductor substrate 101 at the key region e.

The high-voltage opening 116 exposes at least the assistant trench 107. Preferably, the high-voltage opening 116 further exposes a predetermined surface of the semiconductor substrate 101 at both sides of the assistant trench 107. That is, the high-voltage opening 116 has a wider width W3 than the width W1 of the assistant trench 107, preferably. The key opening 117 preferably exposes the initial key trenches 109. The high-voltage opening 116 may be aligned with the assistant trench 107 by aligning the key opening 117 to the initial key trenches 109.

A bottom of the assistant trench 107 and the semiconductor substrate 101 exposed by the cell opening 115, the high-voltage opening 116 and the key opening 117 are anisotropically etched to form a cell trench 120 defining a cell active region, a high-voltage trench 125 defining a high-voltage active region, and a key trench 130.

The cell trench 120 has a shallower depth than the conventional cell trench 4a illustrated in Fig. 2. Since the cell trench 120 has the shallower depth d2, the aspect ratio of the cell trench 120 is decreased compared with a conventional one.

The high-voltage trench 125 is composed of an upper trench 122 at the surface of the semiconductor substrate 101 and a bottom trench 123 at the bottom of the upper trench 122. The upper trench 122 has substantially the same width as the width W3 of the high-voltage

opening 16. The upper trench 122 has substantially the same depth as the cell trench 120. The bottom trench 123 has substantially the same width as the width W1 of the assistant trench 107. The bottom trench 123 under the upper trench 122 has substantially the same depth as the depth d1 of the assistant trench 107. That is, the depth of the high-voltage trench 125 is determined by the sum of the depth d2 of the cell trench 120 and the depth d1 of the assistant trench 107. The bottom surface of the high-voltage trench 125, i.e., the bottom surface of the bottom trench 123, is preferably in contact with the channel stop impurity-doped region 111. Although the stop surface of the channel stop impurity-doped region 111 is in contact with the bottom surface of the bottom trench 123 in the figures, the channel stop impurity-doped region 111 is partially etched while forming the high-voltage trench 125. This is for maintaining a process margin in the etch process.

The key trench 130 is composed of an upper trench 127 at the surface of the semiconductor substrate 101 and bottom key trenches 128 at the bottom of the upper key trench 127. The upper key trench 127 has substantially the same depth as the depth d2 of the cell trench 120, and the bottom key trench 128 under the upper key trench 127 has substantially the same depth as the initial key trench 109.

Then, although not shown, a sidewall oxide (not illustrated) may be formed on inner sidewalls and bottoms of the trenches 120, 125 and 130. The sidewall oxide is for curing the inner sidewalls and the bottoms damaged in the etch process for forming the trenches 120, 125 and 130. The sidewall oxide may be formed of a thermal oxide.

A field insulator 132 is formed on a surface of the semiconductor substrate 101 to fill the cell trench 120, the high-voltage trench 125 and the key trench 130. The field insulator 132 may be formed of silicon oxide.

When the field insulator 132 is formed, since the cell trench 120 has the lower aspect ratio than the conventional cell trench, it is possible to prevent voids in the cell trench 120. Consequently, it is possible to improve reliability problems of a semiconductor device due to the voids.

Referring to Fig. 5, the field insulator 132 is planarized until the trench mask layer 113 is exposed, thereby forming a cell field oxide 132a in the cell trench 120, a high-voltage field oxide 132b in the high-voltage trench 125, and a key field oxide 132c in the key trench 130. The exposed trench mask layer 113 is removed by etching.

In the present embodiment, there is a difference between depths of the cell field oxide 132a and the high-voltage field oxide 132b. That is, the depth of the high-voltage field oxide 132b is a sum of the depth d2 of the cell field oxide 132a and the depth d1 of the bottom

trench 123. Thus, it is possible to minimize a deterioration of punch through characteristic between the source/drain regions (not illustrated) of the high-voltage transistors formed on active regions at both sides of the high-voltage field oxide 132b. Also, it is possible to minimized the phenomenon that threshold voltage of a transistor is increased as a

5 conventional channel stop impurity-doped layer is close to a semiconductor substrate.

Consequently, when the initial key trench 109 is formed, the assistant trench 107 is formed at the high-voltage region d. Therefore, it is possible to form the cell trench 120 having the shallower depth d2 and simultaneously to form the high-voltage trench 125 composed of the upper trench 122 and the bottom trench 123. Thus, voids occurring in

10 conventional field oxides may be prevented and reliability problems of conventional high-voltage transistors may be improved.

In a case of a flash memory device, a high voltage is applied in the cell region c. However, since the high voltage is applied on a gate electrode of a unit cell (not illustrated), although the cell trench 120 has a shallower depth, punch through between unit cells doesn't

15 occur.

#### Second Embodiment.

This second embodiment is similar to the previously described first embodiment of the present invention. However, in this second embodiment, a bottom trench has a wider width than a channel stop impurity-doped region, but narrower than an upper trench.

20 Figs. 6 through 9 illustrate cross-sectional views of semiconductor devices for showing a method of forming field oxides according to another embodiment of the present invention.

Referring to Fig. 6, an assistant trench mask layer 103 is formed on a surface of a semiconductor substrate 101 having a cell region c, a high-voltage region d and a key region e.

25 The assistant trench mask layer 103 is patterned to form an assistant trench opening 140 exposing a predetermined region of the semiconductor substrate 101 at the high-voltage region d, and to form an initial key opening 106 exposing a predetermined region of the semiconductor substrate 101 at the key region e. The assistant trench opening 140 has a predetermined width W1'. At this time, the width W1' of the assistant trench opening 140 is wider than one of the first embodiment.

The semiconductor substrate 101 exposed by the assistant trench opening 140 and the initial key opening 106 is selectively etched to form an assistant trench 142 at the high-voltage region b and an initial key trench 109 in the key region d.

The assistant trench 142 has substantially the same width as the width W1' of the assistant trench opening 140. The assistant trench 142 has a predetermined depth d1 identical with the initial key trench 19.

Referring to Fig. 7, the assistant trench mask layer 103 is removed from the 5 semiconductor substrate 101 having the assistant trench 142.

Then, an ion-implantation mask layer 144 is formed on the semiconductor substrate 101 and patterned to form an ion-implantation opening 146 exposing a predetermined region of the bottom surface of the assistant trench 142. At this time, the cell region c and the key region d may be covered by the ion-implantation mask layer 144. On the contrary, an 10 opening (not illustrated) may be formed for forming a channel impurity-doped region (not illustrated) at a surface of the semiconductor substrate 101 at the cell region c. An align key of the patterned ion-implantation mask 144 may be aligned by another align key (not illustrated).

The width W2 of the ion-implantation opening 146 is preferably narrower than the 15 width W1' of the assistant trench 142. The ion-implantation mask layer 144 may be formed of a photoresist layer.

Impurity ions are implanted by using the patterned ion-implantation mask layer 144 as a mask, thereby forming a channel stop impurity-doped region 111 apart from the bottom surface of the assistant trench 142 with a depth d2. At this time, the channel stop impurity-doped region 111 preferably has substantially the same width as the width W2 of the ion-implantation opening 146.

Referring to Figs. 8 and 9, the patterned ion-implantation mask layer 144 is removed from the semiconductor substrate 101 having the channel stop impurity-doped region 111. Then, a trench mask layer 113 is formed on a surface of the semiconductor substrate 101.

The trench mask layer 113 is patterned to form a cell opening 115 exposing a 25 predetermined region of the semiconductor substrate 101 at the cell region c, to form a high-voltage opening 116 exposing a predetermined region of the semiconductor substrate 101 at the high-voltage region d and to form a key opening 117 exposing a predetermined region of the semiconductor substrate 101 at the key region e. At this time, the width W3 of the high-voltage opening 116 is preferably wider than the width W1' of the assistant trench 142. That 30 is, the width W1' of the assistant trench 142 is wider than the width W2 of the channel stop impurity-doped region 111, but narrower than the width W3 of the high-voltage opening 116.

The exposed semiconductor substrate 101 is anisotropically etched to form a cell trench 120 defining a cell active region at the cell region c, a high-voltage trench 150

defining a high-voltage active region at the high-voltage region d, and a key trench 130 at the key region e.

The cell trench 120 preferably has a shallower depth than a conventional cell trench. The high-voltage trench 150 is composed of an upper trench 148 formed at the surface of the semiconductor substrate 101 and a bottom trench 149 formed at the bottom surface of the upper trench 148. The upper trench 148 has substantially the same depth as the depth d2 of the cell trench 120. The bottom trench 149 under the upper trench 148 has the identical depth with the depth d1 of the assistant trench 142. The bottom trench 149 is preferably in contact with the channel stop impurity-doped region 111. The key trench 130 is composed of an upper key trench 127 and a bottom key trench 128 like the first embodiment.

A field insulator 132 is formed on a surface of the semiconductor substrate 101 to fill the trenches 120, 150 and 130. The field insulator 132 is planarized until the trench mask layer 113 is exposed, thereby forming a cell field oxide 132a in the cell trench 120, a high-voltage field oxide 132b' in the high-voltage trench 150, and a key field oxide 132c in the key trench 130. The exposed trench mask layer 113 is removed.

The trench mask layer 113 and the field insulator 132 may be formed of the identical layers explained in the first embodiment.

Consequently, the cell trench 120 has the shallower depth d2 than a conventional one, thereby preventing voids. Also, with the upper and bottom trenches 148 and 149, the high-voltage trench 150 has the deeper depth than the depth d2 of the cell trench 120. Thus, reliability problems of the conventional high-voltage transistor may be improved.

Furthermore, in the present embodiment, the width W1' of the assistant trench 142 determining the width of the bottom trench 149 is wider than the width W2 of the channel stop impurity-doped region 111 and narrower than the width W3 of the upper trench 148. As a result, it is possible to maintain a process margin with respect to the width W1' of the assistant trench 142.

### Third Embodiment.

In this third embodiment of the invention, an assistant trench for a high-voltage trench is not formed. That is, an upper trench and a bottom trench of the high-voltage trench are sequentially formed.

Figs. 10 through 13 illustrate cross-sectional views of semiconductor devices for showing a method of forming field oxides according to still another embodiment of the present invention.

Referring to Fig. 10, a semiconductor substrate 201 having a cell region c, a high-voltage d and a key region e are selectively etched to form an initial key trench 203 in the key region e.

An ion-implantation mask layer 205 is formed on a surface of the semiconductor 5 substrate 201 having the initial key trench 203. The ion-implantation mask layer 205 is patterned to form an ion-implantation opening 207 exposing a predetermined region of the semiconductor substrate 101 at the high-voltage region d. At this time, another opening (not illustrated) may be formed at the cell region c in order to implant impurity ions for controlling a threshold voltage of a cell transistor (not illustrated). The ion-implantation 10 mask layer 205 may be formed of a photoresist layer. The mask pattern may be aligned by another align key when the ion-implantation opening 207 is formed.

Impurity ions are implanted by using the patterned ion-implantation mask layer 205 as a mask, thereby forming a channel stop impurity-doped region 209 in the semiconductor substrate 201 apart from the surface of the exposed semiconductor substrate 201 with a 15 predetermined depth Da. Then, although not illustrated, other impurity ions are implanted into the exposed semiconductor substrate 101 at the cell region c, thereby forming a surface impurity-doped layer (not illustrated).

Referring to Fig. 11, the patterned ion-implantation mask 205 is removed from the semiconductor substrate 201 having the channel stop impurity-doped region 209. Then, a 20 first trench mask layer 211 is formed on the semiconductor substrate 201. The first trench mask layer 211 may be formed by a hard mask layer or a photoresist layer. The hard mask layer may be formed of sequentially stacked buffer oxide and silicon nitride.

The first trench mask layer 211 is patterned to form a cell opening 213 exposing a predetermined region of the semiconductor substrate 201 located at the cell region c, an upper 25 trench opening 214 exposing a predetermined region of the semiconductor substrate 201 at the high-voltage region d, and a key opening 215 exposing a predetermined region of the semiconductor substrate 201 at the key region 2. The upper trench opening 214 has a predetermined width Wb. The key opening 215 may preferably expose the initial key trenches 203.

30 The exposed semiconductor substrate 201 is selectively etched to from a cell trench 220 defining a cell active region at the cell region c, an upper trench 223 defining a high-voltage active region at the high-voltage region d and a key trench 230 in the key region e. The cell trench 220 has a shallower depth Db than a conventional one. The upper trench 223 has the identical width as the width Wb of the upper trench opening 214. The upper trench

223 has substantially the same depth as the depth  $D_b$  of the cell trench 220. The key trench 230 is composed of an upper key trench 228 formed at the surface of the semiconductor substrate 230 and a bottom key trench 229 formed at the bottom surface of the upper key trench 228.

5 Referring to Fig. 12, the first trench mask layer 211 is removed by etching from the semiconductor substrate 201 having the upper trench 223, and a second trench mask layer 232 is formed on a surface of the semiconductor substrate 201. The second trench mask layer 232 may be formed by a photoresist layer.

10 The second trench mask layer 232 is patterned to form a bottom trench opening 234 exposing a predetermined region of the bottom surface of the upper trench 223. At this time, the cell region c may be covered by the second trench mask layer 232. The key region e may be aligned by exposing another align key (not illustrated).

15 The bottom surface of the exposed upper trench 223 is selectively etched to form a bottom trench 224. The bottom surface of the bottom trench 224 is preferably in contact with the channel stop impurity-doped region 209. A width  $W_c$  of the bottom trench 224 is preferably narrower than the width  $W_a$  of the upper trench 223. Furthermore, the width  $W_c$  of the bottom trench 224 is equal to or wider than the width  $W_a$  of the channel stop impurity-doped region 209. The upper and bottom trenches 223 and 224 compose the high-voltage trench 225. As a result, the depth of the high-voltage trench 225 is a sum of the depth  $D_b$  of the cell trench and the depth  $D_c$  of the bottom trench under the upper trench 223.

20 The channel stop impurity-doped region 209 may be formed after forming the upper trench 223. On the contrary, the channel stop impurity-doped region 209 may be formed after forming the bottom trench 224.

25 Referring to Fig. 13, the second trench mask layer 232 is removed from the semiconductor substrate 202 having the high-voltage trench 225, thereby exposing the cell trench 220, the high-voltage trench 225 and the key trench 230.

Then, a field insulator (not illustrated) is formed on a surface of the semiconductor substrate 201 to fill the exposed cell trench 220, the high-voltage trench 225 and the key trench 230. The field insulator is planarized until the semiconductor substrate 201 is exposed, thereby 30 forming a cell field oxide 235 filling the cell trench 220, a high-voltage field oxide 237 filling the high-voltage trench 225 and a key field oxide filling the key trench 230.

Consequently, the cell trench 220 has a shallower depth than a conventional one, it is possible to prevent voids. Simultaneously, since the depth of the high-voltage trench 225 is

the sum of the depth  $D_b$  of the cell trench 220 and the depth  $D_c$  of the bottom trench 224, it is possible to improve reliability problems of a conventional high-voltage transistor.

As described above, according to the present invention, a cell trench is shallowly formed in comparison with a conventional one, and simultaneously, a high-voltage trench composed of an upper trench having substantially the same depth as the cell trench and a bottom trench formed at the bottom surface of the upper trench is formed. Consequently, an aspect ratio of the cell trench is decreased, thereby preventing voids. Also, the high-voltage trench has a deeper depth than the cell trench, thereby improving reliability problems of high-voltage transistors.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purpose of limitation, the scope of the invention being set forth in the following claims.